Experiment Command and Telemetry Definitions

C.1 Experiment Commands

Each experimenter must define all the commands that are relevant to their experiment. These commands can be either experiment serial commands or carrier commands that control power or command sequences. The experimenter will be required to incorporate their command complement into command sequences and each command will need to identify the expected command response. These command sequences are stored in the SET Carrier's processor memory and can be issued to the experiment in response to an event, a command from the host spacecraft, a command from the ground via the host spacecraft or repetitively as part of a set of relative time sequences. In this appendix the experimenter will find a set of questionnaires and forms that will help the experimenter define their commands and telemetry. The required forms are:

- C-1 Power States and Electrical Interfaces
- C-2 Experiment Serial Commands
- C-3 Experiment Command Sequences
- C-4 Experiment Command Response Message

The forms will be used by:

- The SET flight software team to create the memory load image for the flight processor.
- The SET ground software team to populate the database used for extracting any pertinent telemetry from the SET primary data stream for identifying health and status and to create command uploads.
- The SET Integration and Test team to develop and execute test procedures.
- The SET operations team to help them understand how the experiment is to be operated.

C.1.1 Experiment Minimal Command Set

Each experiment shall define a minimal set of commands. These commands are:

1) RESET command. All experiments shall implement a RESET command. The experiment may, at their discretion, use the electrical RST pulse signal available to them as specified in section 6.2.1.2, Digital Interface. If the experimenter chooses not to use the RST pulse, they shall define an experiment serial command to cause the experiment to reset.
2) STANDBY/NORMAL mode commands. All experiments that employ a standby mode shall implement a STANDBY command. The experiment may, at their discretion, use the electrical STANDBY signal as specified in section 6.2.1.2, Digital Interface to indicate standby mode or normal mode. If the experimenter chooses not to use the STANDBY electrical signal and intends to implement a standby mode, they shall define two experiment serial commands to cause the experiment to enter standby mode and to enter normal mode.
3) PWRON command. All experimenters shall identify which of the available voltages are required to be on for the experiment to be considered fully powered. If a specific order is required, the experimenter shall identify the proper sequence with integers where one (1) is the first to be powered. If a time delay is necessary between the powering on of each different voltage, the experimenter shall indicate the delay as the number of whole seconds since the previous step. For example, if an experiment requires three voltages, 3.3 digital, 5.0 digital and 5.0 analog and there is a required delay of 1 second between the 3.3 digital and the 5.0 digital and a five second delay between the 5.0 digital and the 5.0 analog power, then the experiment should have a table that looks like Table C-1.
4) LOWPWRON command. If an experiment implements a low-power mode, they shall identify which of the available voltages are required to be on for the experiment to be considered in a low power state (See example above).
5) PWROFF command. The experimenter shall identify any sequence required for powering down the experiment and any delays as shown in the PWRON sequence example above.
6) TLMREQ command. All experiments that have telemetry beyond the standard experiment telemetry of dosimeter, temperature and the two experimenter defined analog values, shall supply at least one TLMREQ command. This command shall be an experiment serial command whose response will be treated as an experiment telemetry packet. For further information on defining the characteristics of your telemetry, see the section “Experiment Command Responses” below.

Table C-1 Experiment Power Setting Example (3 voltages)

Voltage Source	Powered On Mode (PWRON)	Power On Order	Power On Delay (sec)	Power Off Order	Power Off Delay (sec)	Low Power Mode (LOWPWRON)
+3.3 Volts (Digital)	☒On ☐ Off	1	N/A	3	1	☐On ☒Off
+5.0 Volts (Digital)	☒On ☐ Off	2	1	2	5	☐On ☒Off
+5.0 Volts (Analog)	☒On ☐ Off	3	5	1	N/A	☒On ☐Off
-5.0 Volts (Analog)	☐On ☒ Off	N/A	N/A	N/A	N/A	☐On ☒Off
+15.0 Volts (Analog)	☐On ☒ Off	N/A	N/A	N/A	N/A	☐On ☒Off
-15.0 Volts (Analog)	☐On ☒ Off	N/A	N/A	N/A	N/A	☐On ☒Off
+28 Volts	☐On ☒ Off	N/A	N/A	N/A	N/A	☐On ☒Off

Experiment Title:	**Page 1 of 2**

C-1.1 Experiment Nominal and Low Power Settings
Identify which power settings your experiment requires for the nominal mode and for a low power (or power conservation) mode:

Voltage Source	Powered On Mode (PWRON)	Power On Order	Power On Delay (sec)	Power Off Order	Power Off Delay (sec)	Low Power Mode (LOWPWRON)
+3.3 Volts (Digital)	☐On ☐Off					☐On ☐ Off
+5.0 Volts (Digital)	☐On ☐Off					☐On ☐ Off
+5.0 Volts (Analog)	☐On ☐Off					☐On ☐ Off
-5.0 Volts (Analog)	☐On ☐Off					☐On ☐ Off
+15.0 Volts (Analog)	☐On ☐Off					☐On ☐ Off
-15.0 Volts (Analog)	☐On ☐Off					☐On ☐ Off
+28 Volts	☐On ☐Off					☐On ☐ Off

NOTE: Low power mode may or may not correspond to an experiment's standby mode or to the carrier's safe mode.

Experiment Title:	**Page 2 of 2**

C-1.2 Experiment Reset/Standby Command Implementation
Identify the method in which your experiment will implement the required RESET command and information on the optional STANDBY command:

	Yes/No	Notes
Does your experiment use the electrical RST signal to perform a RESET?	☐Yes ☐No	If answer is "No," then the experimenter **must** provide an experiment serial command for RESET.
Will your experiment implement a STANDBY mode?	☐Yes ☐No	If answer is "No", then enter "N/A" below
Will the experiment use the electrical STANDBY signal to control STANDBY mode?	☐Yes ☐No ☐N/A	If answer is "No," then the experimenter **must** provide an experiment serial command for entering STANDBY and NORMAL modes

C-1.3 Experiment RS-422 Baud Rate

Identify the baud rate the experiment will use when communicating over the RS-422 Serial Interface: ___________

C.1.2 Experiment Serial Commands

Form C-2 consists must be filled out for *each* experiment serial command.
The form contains the following fields:

- **Experiment Title** – the experiment's name.
- **Command Title** – a brief title identifying the command's purpose
- Command Mnemonic - an experiment unique command mnemonic that will be used in later forms to create the experimenter's command sequences. It should be noted that these command mnemonics are for documentation purposes only. Experimenter commands are not, typically, going to be contained in a ground system command database. They reside only in the memory of the Carrier processor and are executed/issued indirectly via an experimenter defined command sequence.
- **Description** – a brief description of the purpose of the command.
- **Protocol** - a selection for the protocol to be employed when transmitting the command to the experiment.
- **HDLC Unbalanced Connectionless** – check this box if the experiment uses the HDLC Unbalanced Connectionless communication protocol described in Section HDLC-Unbalanced Connectionless Class, *UCC12,15.1*
    - o **Experiment Defined** – check this box if the experiment is using a protocol
    - o **Uses NZF** – check this box if the experiment data implements a protocol that indicates whether data is available or not with a Non-Zero Flag in the first byte of the command response message
    - o **NZF Bit Mask** – a bit mask, specified in hexadecimal, that identifies the bit or bits in the first byte of the command response message that will indicate the presence of science data when non-zero
- **Response Timeout** – the maximum number of milliseconds it should take for the experiment to respond with a command response data packet.
- **Cmd Failure Sequence #** – the experimenter can optionally specify a the number of a command sequence that should be executed if the command encounters an error on transmission or fails to respond.
- Issue Event Message? - if the execution of a command modifies the operational state of the experiment (e.g. - power, science mode, etc), then the command is required to be associated with an event message.
- **Is response Telemetry?** – identifies whether the command response packet should be treated as telemetry and queued for output to the primary data stream to the host spacecraft. If the experiment is also using the NZF protocol, then the NZF must also be non-zero for the data to be queued for output. A packet name must be specified to identify the format of the returned data for any further processing by the carrier software.
- **Cmd Response Name –** the name corresponding to the command response packet defined below.
- **Remaining boxes –** the content of the information field for the command as issued to the experiment. These bytes should be defined in hex format to avoid confusion.

Experiment Title:

Command Title: | **Command Mnemonic:**

Description:

Protocol:
☐ **HDLC Unbalanced Connectionless**
☐ **Experiment Defined**
☐ **Uses NZF**
NZF Bit Mask: (in hex)

Response Timeout (msecs):
Cmd Failure Sequence #:
Issue Event Msg? ☐ **Y # (hex)**
Is response telemetry? ☐ **Y** ☐ **N**
Cmd Response Name:

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127

C.1.3 Experiment Command Sequences

Once an experimenter has defined all of their commands, they are then required to organize those commands into command sequences. The experimenter should duplicate the Form C-3 for each command sequence they wish to define.

A command sequence consists of a set of experiment serial or carrier commands that are capable of being executed within a single 40 millisecond experiment time slice (ETS). Each experiment will be allocated a minimum of one ETS per second. It is critical that the experimenter ensures that the command sequence can complete within their allotted ETS of 40 milliseconds.

Additional ETSs will only be allocated to an experiment if the payload configuration for a particular mission allows for the additional bandwidth (e.g. – fewer than the maximum number of experiments have been selected for the mission, bandwidth between carrier and host spacecraft is sufficient to accept the additional data, etc.).

At any time during the mission, a command sequence can be in one of three states. These states are defined as:

- **Disabled, Inactive** – This state indicates that the sequence will not execute until both enabled, via ground command, and activated via a command sequence activation command.
- **Enabled, Inactive** – This state indicates that the sequence will not execute but could be moved to the Enabled, Active state via a command sequence activation command.
- **Enabled, Active** – This state indicates that the sequence is ready to execute and will execute during the experiment's next ETS assuming the command sequence is not "bumped" by another "Enabled, Active" sequence of higher priority (see the definition of "priority" below).

Command sequences should only be moved from the "Disabled, Inactive" state to the "Enabled, Inactive" state via ground command. The experimenter may wish to disable a sequence or sequences upon detection of an error. This will prevent those command sequences from executing until the ground operations team determines that it is safe to do so.

The experimenter should assign a number to each of their command sequences. The first command sequence number should be zero, then one, etc.

Command sequences have various properties to provide the experimenter with the ability to define their routine telemetry collection scheme, change their data acquisition or change their current mode of operation based upon real-time data monitoring. These properties and their effects are described below:

- **Priority** – Each command sequence is defined with a priority of 0 to 15 where 0 is the lowest and 15 is the highest. If during the start of an experimenter's ETS the carrier software determines that there are two command sequences that are active, then the sequence with the highest priority will execute. The other sequence will remain active, unless their "bump limit" (see below) is exceeded, and will attempt to be executed during the experimenter's next ETS.
- **Repeat Count** – Defines the number (0 to 65535) of times the sequence is to execute before automatically deactivating itself. Each execution will occur on the experimenter's consecutive ETSs. If the repeat count is set equal to zero, the

sequence will never automatically deactivate itself and will remain in the "Enabled, Active" state until a carrier command to disable or deactivate the sequence is processed.

- **Cycle Offset** – Defines the number of ETSs the sequence must wait before attempting execution. For example, if a command sequence has a repeat count of one (1) and a cycle offset of three (3) at time equals zero (0), then the sequence will skip time equals zero, one and two and execute at time equals three.
- **Bump Limit** – Defines the number (0 to 65535) of consecutive ETSs that an "Enabled, Active" sequence can be bumped by any higher priority sequences before automatically deactivating itself. If set equal to zero, the command sequence can be bumped by any higher priority sequences indefinitely.

C.1.3.1 Available Carrier Commands

In addition to containing experiment serial commands, each experimenter's command sequence can contain carrier commands to disable, activate and/or deactivate other command sequences. When specifying the experiment's command sequences, the experimenter should use the following command mnemonics to identify carrier commands:

- **DISABLESEQ <#>** - where <#> is one of an experimenter's sequence numbers. This command will disable the specified sequence and prevent its activation until the sequence is enabled via ground command. The command will move a sequence that is in either the "Enabled, Active" state or the "Enabled, Inactive" state to the "Disabled, Inactive" state.
- **ACTIVATESEQ <#>** - where <#> is one of an experimenter's sequence numbers. This command will move a sequence that is in the "Enabled, Inactive" state to the "Enabled, Active" state.
- **DEACTIVATESEQ <#>** - where <#> is one of an experimenter's sequence numbers. This command will move a sequence that is in the "Enabled, Active" state to the "Enabled, Inactive" state.

C.1.3.2 Analog Channel Sampling

The experiment can also request the reading of the 4 analog channels associated with their experiment. Any one or combination of these analog channels can be sampled once per ETS. However, the order in which they are sampled is fixed and determined by the Power Control Card hardware. The experimenter must group the samples contiguously in a command sequence.

- **READDOSE** – sample the dosimeter attached to the experiment
- **READTEMP** – sample the thermistor attached to the experiment
- **READANALOG1** – sample the first experiment defined analog channel
- **READANALOG2** – sample the second experiment defined analog channel

Experiment Title:	
Command Sequence Name:	**Command Sequence Number:**
Priority (0 [low] to 15 [high]):	**Repeat Count (secs):**
Cycle Offset (secs):	**Bump Limit (secs):**
Command Mnemonic	**Notes**

C.2 Experiment Command Responses

In response to a command, the experiment is required to send data back to the carrier. If the experimenter has identified this data in the command definition form above as telemetry data, then the carrier will apply the appropriate CCSDS telemetry header to the data and queue it for output to the host through the primary serial data stream. The experimenter can identify a portion of these messages so that they can be properly processed by the carrier flight software as well as decommutated from the primary data stream by the ground data processing software. Telemetry points are required to be defined if their contents are to be used in the definition of an experimenter data monitor rule as defined below. For each data message that is to be returned, the following form is necessary.

- **Packet Name** – an experiment unique name that can be used to identify the packet with its associated experiment serial command.
- **Is Message Telemetry?** – this field identifies whether the carrier software should prepend a CCSDS header to the message and queue it to the telemetry output stream to the host spacecraft.
- **CCSDS APID** – the experimenter should leave this field blank. The SET flight software team will assign application IDs to all of the packets for a particular mission.
- **Message Length** – the *maximum* number of bytes in the response message.
- **Field Type** – the experimenter should identify the data type of each data element in the data message. The field types can be any of the types outlined in Table C-2.

Table C-2 Experiment Command Response Fields

Field Specifier	Definition	Field Specifier	Definition
U1	Unsigned 8-bit integer	U1234	Unsigned 32-bit big-endian integer
S1	Signed 8-bit integer	U4321	Unsigned 32-bit little-endian integer
U12	Unsigned 16-bit big-endian integer	S1234	Signed 32-bit big-endian integer
U21	Unsigned 16-bit little-endian integer	S4321	Signed 32-bit little-endian integer
S12	Signed 16-bit big-endian integer	F1234	IEEE STD 754 Floating Point Number in big-endian format
S21	Signed 16-bit little-endian integer	F4321	IEEE STD 754 Floating Point Number in little-endian format

- **Byte Offset** – the number of bytes from the beginning of the command response message to the beginning of the data point being defined. Note that the first byte of the command response has a byte offset of zero.

- **Mnemonic** – the experimenter should assign a mnemonic to each value to facilitate its identity in the ground software and in any experiment data monitor rules below. The mnemonic should follow the following naming conventions:
    - It should not be greater than 9 characters in length
        - NOTE: A three character prefix may be prepended to the experimenter's defined mnemonic to uniquely identify the mnemonic for a particular payload configuration.
    - The characters must be alphanumeric (A-Z,0-9) with the first character a letter.
    - Electrical voltages should be identified with either "V" or "VLT"
    - Electrical currents should be identified with either "I" or "CUR"
    - Temperature readings should be identified with either "T" or "TMP"
    - Enable/Disable status should be identified with "EN" or "DIS".
    - On/Off status should be identified with "ON" or "OF".
    - Mnemonics associated with binary discrete telemetry should indicate the state when the discrete is equal to one (1) (e.g. – a power status mnemonic should be named with "ON" when the telemetered value of "1" indicates powered-on and "OF" when a "1" indicates powered-off).
- **Description** – a brief description of the content of the data element. If the data point is a subset of the number of bits in the specified field, the bit mask that identifies the pertinent bits should be noted in the description (in hexadecimal).

For example, if the experiment has a byte that indicates the power state of multiple devices, they might define the following mnemonics:

Table C-3 Sample Experiment Command Response Message

Experiment Title: My Sample Experiment			
Command Response Name: Experiment Status Packet			Page #: 1
CCSDS APID:		Max Msg Length: 1	Is Message Telemetry? ☒ Yes ☐ No
Field Type	**Byte Offset**	**Mnemonic**	**Description**
U1	0	DEV1PWRON	Device 1 Power On Status BITMASK = 80H
U1	0	DEV2PWRON	Device 2 Power On Status BITMASK = 40H
U1	0	DEV3PWRON	Device 3 Power On Status BITMASK = 20H
U1	0	DEV4PWRON	Device 4 Power On Status BITMASK = 10H
U1	0	DEV1PWREN	Device 1 Power Enable Status BITMASK = 08H
U1	0	DEV2PWREN	Device 2 Power Enable Status BITMASK = 04H
U1	0	DEV3PWREN	Device 3 Power Enable Status BITMASK = 02H
U1	0	DEV4PWREN	Device 4 Power Enable Status BITMASK = 01H

The first page of Form C-4 should be used as the first page for each different command response message. The second page of Form C-4 should be used as many times as necessary to define all of the pertinent data points within a particular command response message.

Experiment Title:			
Command Response Name:			Page #: 1
CCSDS APID:		Max Msg Length:	Is Message Telemetry? ☐ Yes ☐ No
Field Type	Byte Offset	Mnemonic	Description

Experiment Title:			
Command Response Name:			**Page #:**
Field Type	**Byte Offset**	**Mnemonic**	**Description**

C.3 Experiment Data Monitors

C.3.1 Data Monitoring Rule Definitions

Experimenters have the option of defining Data Monitors for their command response data. A Data Monitor allows an experimenter to extract a data point from a command response message and compare (using less than, equal, or greater than) the value of that data point with a constant. If the comparison passes, the Data Monitor can either "Activate" a command sequence, thus allowing an experiment to change its mode of operation to accommodate the change in environment or set/clear one of a set of 32 flags that the experiment is assigned. These flags can also be used in Data Monitor rules. Data Monitors are also capable of performing combinatorial logic. A single Data Monitor rule can require multiple comparisons to be TRUE before the specified command sequence is "Activated" (this is called a logical "AND" clause). Similarly, a single Data Monitor rule can require any one of multiple comparisons to be TRUE before the specified command sequence is "Activated" (this is called a logical "OR" clause). The experimenter is free to express their Data Monitor rules in plain English. An example of how an experimenter might define a set of Data Monitors can be see below:

- ***IF (DEV1PWRON = 0) THEN START SEQUENCE 12***
- ***IF (DEV2PWRON = 0) AND (DEV3PWRON = 0) THEN START SEQUENCE 13***
- ***IF (DEV1PWREN = 0) OR (DEV2PWREN = 0) OR (DEV3PWREN = 0) OR (DEV4PWREN = 0) THEN START SEQUENCE 14***
- ***IF (DEV1PWRON = 1) AND (DEV2PWRON = 1) THEN SET FLAG 3***
- ***IF (DEV3PWRON = 1) OR (DEV4PWRON = 1) THEN SET FLAG 4***

The experimenter should create a set of statements similar to the above with comments to help operations and flight software personnel determine the purpose and objective of the Data Monitor (i.e. – science, safety, etc).

C.3.2 CEM Data Monitors

Data Monitors can also be defined for the data obtained from the Carrier's CEM. The experimenter will be given the appropriate mnemonic names for the data points provided by the selected CEM for their particular mission. The experimenter can then use these mnemonics to write their desired Data Monitors. These tests can allow an experiment to change their science taking mode depending upon the detected environment in which the payload is flying.
CEM providers shall be required to define all scientifically relevant data points that could be utilized in data monitoring rules for other experiments at the CEM Experiment Design Review.